Effect of blade tenderization, aging time, and aging temperature on tenderness of beef longissimus lumborum and gluteus medius[1,2]

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ABSTRACT: Purveyors are concerned about the potential food safety risk of nonintact meat products and are seeking strategies to ensure adequate meat tenderness without blade tenderization. This study was conducted to determine the effects of blade tenderization and time and temperature of aging on beef longissimus lumborum (LL) and gluteus medius (GM) tenderness. Beef strip loins (n = 300) and top sirloin butts (n = 300) were assigned to storage at −0.5 or 3.3°C for 12, 26, or 40 d. Cuts were blade tenderized (BT) or not blade tenderized (NBT) before steak cutting. One 2.54-cm steak from each subprimal was used for slice shear force determination and Western blotting of desmin. Desmin degradation was less ($P < 0.05$) in LL stored at −0.5°C than LL stored at 3.3°C (57 and 65%, respectively). Aging from 12 to 26 d increased ($P < 0.05$) proteolysis (50 to 65%) in LL. Regardless of aging time, BT reduced ($P < 0.05$) LL slice shear force values. Aging time did not affect ($P > 0.05$) slice shear force values of BT LL steaks (10.4, 9.9, and 9.4 kg for 12, 26, and 40 d aging, respectively), but reduced ($P < 0.05$) NBT steak slice shear force values (15.1, 13.8, and 12.3 kg for 12, 26, and 40 d aging, respectively). Greater temperature did not affect ($P > 0.05$) slice shear force values of BT LL steaks (10.2 and 9.6 kg for steaks aged at −0.5 and 3.3°C, respectively), but improved ($P < 0.05$) slice shear force of NBT LL steaks (15.1 and 12.4, respectively). Aging at 3.3°C increased ($P < 0.05$) proteolysis in GM steaks (43 and 54% for −0.5 and 3.3°C, respectively). Longer aging times increased ($P < 0.05$) proteolysis (40, 46, and 60% for 12, 26, and 40 d aging, respectively) in GM steaks. Blade-tenderized GM steaks had dramatically less ($P < 0.05$) slice shear force values than NBT steaks (13.7 and 19.9 kg, respectively). Raising aging temperature from −0.5 to 3.3°C reduced (17.6 vs. 16.0 kg; $P < 0.05$) and increasing aging time from 12 d to 40 d improved (17.9 vs. 15.2 kg; $P < 0.05$) slice shear force values of GM steaks. Blade tenderization and increased aging time and temperature all improved tenderness of beef LL and GM steaks, though blade tenderization provided greater improvements than increased aging time and temperature. Longer aging could potentially be used to replace blade tenderization for LL steaks, but not in GM steaks.

Key words: aging, beef, blade tenderization, tenderness temperature

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INTRODUCTION

Blade tenderization is widely used by purveyors to ensure meat tenderness (George-Evins, 1999) because it has been reported as an effective intervention for meat from animals with inherent challenges with regard to tenderness (Smith et al., 1979b; Seideman et al., 1986; Wheeler et al., 1990).

Despite its widespread use, mechanically tenderized beef has been defined as nonintact by the Food Safety and Inspection Service (FSIS-USDA, 1999). When very large numbers of pathogenic microorganisms contaminate a subprimal surface, those pathogens could potentially be translocated to the interior of the muscle (Sporing, 1999). Therefore, steaks not cooked to an internal temperature of at least 60°C could po-

[1]Mention of trade names, proprietary products, or specified equipment does not constitute a guarantee or warranty by the USDA and does not imply approval to the exclusion of other products that may be suitable. Anti-desmin (clone D3) was developed by D. A. Fischman and obtained from the Developmental Studies Hybridoma Bank maintained by the University of Iowa, Department of Biological Science, Iowa City 52242, under contract N01-HD-7-3263 from the NICHD. The authors are grateful to Patty Beska, Peg Ekeren, Kathy Mihm, and Pat Tammen (US Meat Animal Research Center, Clay Center, NE) for their assistance in the execution of this experiment and to Marilyn Bierman (US Meat Animal Research Center, Clay Center, NE) for her secretarial assistance.

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tentially pose a food safety risk (Sporing, 1999; Laine et al., 2005). Most purveyors consider this as a risk not reasonably likely to occur and focus on sanitation of tenderization equipment. However, foodborne illness outbreaks have been associated with nonintact beef products (Laine et al., 2005).

Thus, purveyors seek a noninvasive strategy for ensuring the tenderness of their products. The simplest tenderization strategy available to purveyors is postmortem aging. The tenderization effects of aging are a result of the cleavage of cytoskeletal proteins by the calpain enzyme system, which is affected by temperature (Koohmaraie et al., 1986; Zeece et al., 1986; Koohmaraie, 1992). Altering ambient temperatures during chilling has been reported to influence proteolysis and tenderness (Whipple et al., 1990; King et al., 2003). However, it is not clear whether relatively small changes in postrigor storage temperature would affect tenderization during extended aging. The present study was designed to compare the effectiveness of blade tenderization and extended postmortem storage at −0.5 or 3.3°C on longissimus lumborum and gluteus medius tenderness.

MATERIALS AND METHODS

Animal Care and Use Committee approval was not obtained for this study because the samples were obtained from a federally inspected slaughter facility.

Selection and Handling of Product

Three hundred beef, loin, strip loin, boneless [International Meat Purchasing Specification (**IMPS**) 180; USDA, 1996; NAMP, 2003] and 300 beef, loin, top sirloin butt, center-cut, boneless, cap off (IMPS 184B; USDA, 1996; NAMP, 2003) were selected from the fabrication lines at a large commercial beef processing facility. Subprimals were selected from commodity USDA Choice carcasses and were blocked by production lot (i.e., feedlot pen) as they were assigned to aging temperature (−0.5 or 3.3°C), aging time (12, 26, or 40 d), and blade tenderization (blade tenderized or not blade tenderized) treatments in a 2 × 3 × 2 factorial arrangement. The aging times used in this study were designed to represent short, intermediate, and long storage times likely to be found in commercial practice. The short aging time was selected to be well within aging times observed in the retail and food-service trade. Very early postmortem aging times were not studied because, due to distribution logistics, food-service steaks would not likely be consumed at very early postmortem times. Steaks stored for the shortest period were evaluated at 15 d postmortem, which approximates a common retail aging time as reported by Brooks et al. (2000). The intermediate aging period approximated the mean aging times for food-service steaks reported by the National Beef Tenderness Survey (Brooks et al., 2000). The long aging time was intended to represent an extended, yet still practical, aging protocol that was well within the aging times reported for commercial practice. Additionally, these aging times are consistent with the aging times reported in a more recent survey (Voges et al., 2007), which suggested an industry trend toward longer aging times.

Subprimals were transported via refrigerated (2.4 ± 0.58°C) truck to a large-scale purveyor. Subprimals arrived at the purveyor 3 d postmortem and were stored at the prescribed temperature for an additional 12, 26, or 40 d. Aging temperature was regulated by setting cooler temperatures at −0.5 and 3.3°C. Temperatures recorded by temperature loggers (RD-Temp-XT, Omega Engineering Inc., Stamford, CT) at the product surface indicated that the mean product temperatures were −0.8 ± 0.64 and 3.0 ± 0.78°C, respectively. Thus, steak cutting was conducted at 15, 29, and 43 d postmortem, respectively, and tenderness evaluations were made at 16, 30, and 44 d postmortem, respectively. After the appropriate length of aging, subprimals were removed from cold storage and one-half of the subprimals from each aging time and temperature combination were subjected to one pass through a blade tenderizer (TC700M, Ross Industries Inc., Midland, VA), whereas the remaining cuts were not blade tenderized. Each cut was trimmed of fat greater than 0.64 cm and accessory muscles. Each strip loin was cut into 2.54-cm-thick steaks using an automated portioning system (model IPM-03-X600, Marel Food Systems Inc., Lenexa, KS). The first full steak from the cranial end of each strip loin was obtained for slice shear force determination. One 2.54-cm-thick steak was hand-cut from the central (anterior to posterior) portion of each center-cut top sirloin butt for slice shear force determination. On the day they were cut, steaks obtained for slice shear force measurement were packed, with ice packs, in insulated containers and transported (approximately 9 h at 2.4 ± 0.32°C) to the US Meat Animal Research Center.

Slice Shear Force Determination

Upon arrival at the US Meat Animal Research Center, steaks were refrigerated at 5°C and allowed to equilibrate for at least 7 h. All steaks were cooked with a belt grill as described by Wheeler et al. (1998). Slice shear force was conducted on longissimus lumborum steaks as described by Shackelford et al. (1999). Sampling for slice shear force of gluteus medius steaks was conducted according to a modification of the procedure of Shackelford et al. (1999) developed at the US Meat Animal Research Center. This modification involved removing 3 slices (1-cm-thick × 5-cm-long) representing the lateral, center, and medial sections of the gluteus medius steak. The slices were removed parallel to the muscle fiber orientation and at a 45-degree angle to the cut surface of the steak. The slices from the lateral and medial sections were oriented perpendicular to the length of the steak (i.e., from the most superficial to the most internal part of the muscle). Conversely, the slice representing the center section was oriented parallel to the length of the steak and was removed from the superficial one-half of the section. Steaks were cooked and sheared at the conclusion of their respective aging treatments (i.e., on d 3). The sheared slices were retained and frozen (−20°C) until utilized for immunoblotting analysis.

Immunoblotting of Desmin

Desmin degradation was assessed by Western blotting on the tissues from slices that had been sheared for slice shear force determination. Immunoblotting and quantification of desmin was conducted as described by Wheeler and Koohmaraie (1999) with a muscle-specific at-death sample loaded into the 2 outside and the center lanes of each gel as an internal standard for normalizing the data and determining the proportion of desmin that had been degraded. Protein (15 μg) from each sample was loaded into the remaining lanes. Samples were assigned to gels and lanes within a gel so that each treatment combination was run in a given lane an equal number of times. Data were expressed as the percentage of at-death desmin remaining at each postmortem aging time.

Statistical Analysis

Data were analyzed as a completely randomized design using the PROC GLIMMIX procedure (SAS Institute Inc., Cary, NC). Data from the longissimus lumborum and gluteus medius were analyzed independently. The model tested the effects of aging time, aging temperature, blade tenderization, and all possible interactions. Least squares means of significant interactions and main effects not involved in higher order interactions were separated using the diff option. A predetermined probability of type I error (α) of 0.05 was used in all determinations of statistical significance.

RESULTS

Longissimus Lumborum

Slice shear force values for longissimus lumborum steaks were affected by a blade tenderization × aging temperature interaction (Table 1). Aging at 3.3°C rather than −0.5°C reduced ($P < 0.05$) slice shear force values of non-blade-tenderized longissimus lumborum steaks by 2.7 kg. However, when blade tenderized, steaks aged at 3.3°C had similar ($P > 0.05$) slice shear force values to those aged at −0.5°C. Additionally, blade-tenderized steaks had statistically less ($P < 0.05$) slice shear force values than non-blade-tenderized steaks regardless of the temperature used during aging. The reduction in slice shear force values attributable to blade tenderization was larger in longissimus lumborum steaks aged at −0.5°C than those aged at 3.3°C.

Blade tenderization also interacted with aging time to affect longissimus lumborum slice shear force values. In non-blade-tenderized longissimus lumborum, increasing aging time from 12 to 26 d reduced ($P < 0.05$) slice shear force values by 1.3 kg, and extending aging time from 26 to 40 d further reduced ($P < 0.05$) slice shear force values by 1.5 kg. However, in blade-tenderized longissimus lumborum steaks, additional aging beyond 12 d (15 d postmortem) did not improve ($P > 0.05$) slice shear force values. Blade-tenderized longissimus lumborum steaks had less ($P < 0.05$) slice shear force values than non-blade-tenderized steaks regardless of aging time. However, the effect of blade tenderization on slice shear force decreased ($P < 0.05$) with prolonged aging.

Blade tenderization had no effect ($P > 0.05$) on postmortem proteolysis of desmin in longissimus lumborum steaks (Table 1). Increasing aging temperature from −0.5 to 3.3°C increased ($P < 0.05$) the proportion of desmin in longissimus lumborum that had been degraded. Thus, proteolysis was significantly increased even by this small increase in storage temperature. Increasing aging time of longissimus lumborum steaks from 12 to 26 d also increased ($P < 0.05$) desmin degradation. Further increasing aging time from 26 to 40 d did not result ($P > 0.05$) in an additional increase in proteolytic degradation in longissimus lumborum.

The effects of blade tenderization and increased aging temperature on tenderness also were evident in the distribution of slice shear force values of longissimus lumborum steaks (Figure 1). When aged at −0.5°C, 100% of blade-tenderized steaks had slice shear force values less than 20 kg. In contrast, 8.2% of non-blade-tenderized steaks aged at −0.5°C had slice shear force values greater than 20 kg. At the greater aging temperature, 100% of blade-tenderized longissimus lumborum steaks had slice shear force values less than 20 kg, whereas 1.4% of non-blade-tenderized steaks had slice shear force values greater than 20 kg. These frequency distributions indicate that increased aging temperature improves the proportion of longissimus lumborum steaks that would produce a positive eating experience.

Cooking losses were affected by a blade tenderization × aging temperature interaction ($P < 0.05$). Blade-tenderized steaks had greater ($P < 0.05$) cooking losses than non-blade-tenderized steaks regardless of aging temperature. Non-blade-tenderized steaks aged at −0.5°C had greater ($P < 0.05$) cooking losses than those stored at 3.3°C. Aging temperature did not affect ($P > 0.05$) cooking losses of blade-tenderized steaks.

Gluteus Medius

Blade tenderization produced a substantial decrease ($P < 0.05$) in slice shear force values of gluteus medius steaks (6.3 kg; Table 2). Additionally, increasing the aging temperature during aging from −0.5 to 3.3°C caused a 1.6-kg ($P < 0.05$) reduction in slice shear force values. Increasing storage time from 12 to 40 d at the prescribed temperature improved ($P < 0.05$) slice shear force values. However, no slice shear force differences (P

Table 1. Least squares means for blade tenderization, aging temperature, and aging time effects on cooking loss (%), slice shear force values (kg), and desmin degradation of longissimus lumborum steaks

Treatment		Cooking loss, %	Slice shear force, kg	Desmin degraded, %
Blade tenderization effect				
Blade tenderized		20.38	9.9	60.4
Non-blade tenderized		19.01	13.7	61.5
SEM		0.11	0.21	1.06
$P > F$		<0.001	<0.001	0.49
Aging temperature effect				
−0.5°C		19.76	12.6	57.2^{y}
3.3°C		19.62	11.0	64.6^{z}
SEM		0.16	0.21	1.06
$P > F$		0.36	<0.001	<0.001
Aging time effect				
12 d		19.22	12.7	50.5^{y}
26 d		19.84	11.9	64.9^{z}
40 d		20.02	10.9	67.4^{z}
SEM		0.14	0.25	1.29
$P > F$		<0.001	<0.001	<0.001
Blade tenderization × aging temperature interaction				
Blade tenderized	−0.5°C	20.28^{z}	10.2^{x}	63.9
Blade tenderized	3.3°C	20.47^{z}	9.6^{x}	56.9
Non-blade tenderized	−0.5°C	19.25^{y}	15.1^{z}	65.4
Non-blade tenderized	3.3°C	18.77^{x}	12.4^{y}	57.5
SEM		0.15	0.30	1.50
$P > F$		0.03	<0.001	0.78
Blade tenderization × aging time interaction				
Blade tenderized	12 d	20.07^{y}	10.4^{w}	52.2
Blade tenderized	26 d	19.99^{y}	9.9^{w}	63.9
Blade tenderized	40 d	21.07^{z}	9.4^{w}	65.2
Non-blade tenderized	12 d	18.37^{w}	15.1^{z}	48.7
Non-blade tenderized	26 d	19.68^{y}	13.8^{y}	65.9
Non-blade tenderized	40 d	18.98^{x}	12.3^{x}	69.7
SEM		0.19	0.36	1.83
$P > F$		<0.001	0.03	0.09

[w–z]Least squares means within a column and within an effect lacking common superscripts differ ($P < 0.05$).

> 0.05) were detected between gluteus medius steaks stored for 12 or 26 d.

Blade tenderization did not affect ($P > 0.05$) desmin degradation of gluteus medius steaks (Table 2). Aging gluteus medius steaks at 3.3°C resulted in a greater percentage ($P < 0.001$) of desmin that had been degraded compared with steaks that had been aged at −0.5°C. Increasing aging time from 12 to 26 d increased the extent of postmortem proteolysis ($P < 0.05$), as did increasing aging time from 26 to 40 d.

The effects of blade tenderization and aging temperature on the distribution of slice shear force values of gluteus medius steaks are shown in Figure 2. The effect of blade tenderization on the distribution of slice shear force values in gluteus medius steaks was much larger than the effect observed in longissimus lumborum steaks. Blade tenderization dramatically increased ($P < 0.05$) the proportion of steaks with reduced slice shear force values. When steaks were aged at −0.5°C, 4% of blade-tenderized steaks had slice shear force values greater than 20 kg compared with 56% of non-blade-tenderized steaks having values greater than 20 kg. The same pattern was observed in gluteus medius steaks aged at 3.3°C. Only 1.4% of blade-tenderized steaks had slice shear force values greater than 20 kg, whereas 23.9% of non-blade-tenderized gluteus medius steaks had slice shear force values greater than 20 kg. It is notable that a small number of steaks that were aged at the elevated temperature and not blade-tenderized had slice shear force values greater than 25 kg. This supports the notion that blade tenderization eliminates the incidence of extremely tough meat. Additionally, it appears that the increased aging temperature improved the distribution of slice shear force values in non-blade-tenderized gluteus medius steaks by increasing the proportion of steaks with slice shear force values less than 20 kg. However, as noted earlier, this effect is small in comparison with the effects of blade tenderization.

Cooking losses were greater ($P < 0.05$) in gluteus medius steaks aged at 3.3°C than in those aged at −0.5°C. Additionally, cooking losses were greater ($P < 0.05$) in gluteus medius steaks stored for 26 d than those aged for 12 or 40 d. Blade tenderization had no effect ($P > 0.05$) on cooking losses of gluteus medius steaks.

DISCUSSION

In both muscles, blade tenderization, increased aging time, and increased aging temperature all reduced slice shear force values. However, the improvement associated with blade tenderization was larger than the effect of increased time or increased temperature during aging, especially in the gluteus medius. The improvement of slice shear force values due to blade tenderization detected in the present study are consistent with previous reports on blade tenderization on longissimus lumborum (Davis et al., 1977; Savell et al., 1977; Seideman et al., 1986) and gluteus medius (Savell et al., 1977; George-Evins et al., 2004).

Non-blade-tenderized longissimus steaks aged for 40 d had slice shear force values that were approximately 2 kg greater than blade-tenderized steaks aged for 12, 26, or 40 d. Though statistically significant, this difference may be too small to adversely affect consumer satisfaction to a large degree. Blade-tenderized longissimus lumborum steaks stored at –0.5°C (across all aging times) had no slice shear force values greater than 20 kg. It should be noted, though, that only 1.4% of the non-blade-tenderized steaks stored at 3.3°C had slice shear force values greater than 20 kg, suggesting that these steaks would be acceptable to consumers. The value of 20 kg was arbitrarily selected to compare these

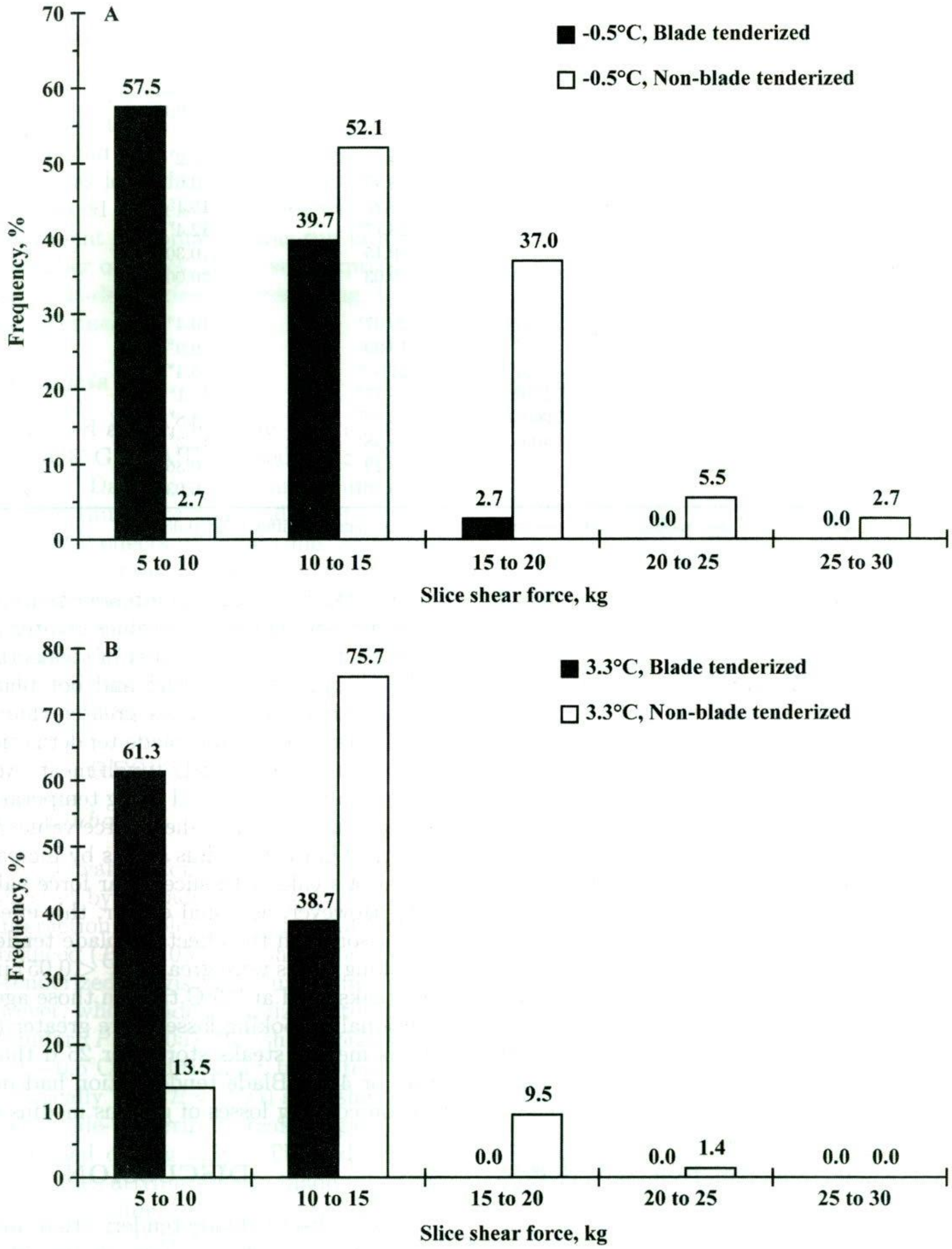

Figure 1. Frequency distribution of slice shear force values for blade-tenderized and non-blade-tenderized longissimus lumborum steaks aged at −0.5°C (A) or 3.3°C (B).

Table 2. Least squares means for blade tenderization, aging temperature, and aging time effects on cooking loss (%), slice shear force values (kg), and desmin degradation (%) of gluteus medius steaks

Treatment		Cooking loss, %	Slice shear force, kg	Desmin degraded, %
Blade tenderization effect				
Blade tenderized		22.68	13.7[y]	49.2
Non-blade tenderized		22.62	19.9[z]	47.7
SEM		0.14	0.30	1.14
$P > F$		0.65	<0.001	0.35
Aging temperature effect				
−0.5°C		22.49[y]	17.6[z]	43.2[y]
3.3°C		22.81[z]	16.0[y]	53.6[z]
SEM		0.10	0.43	1.14
$P > F$		0.02	<0.001	<0.001
Aging time effect				
12 d		22.92[z]	17.9[z]	39.5[x]
26 d		22.35[y]	17.3[z]	46.2[y]
40 d		22.67[z]	15.2[y]	59.5[z]
SEM		0.12	0.37	1.4
$P > F$		<0.01	<0.001	<0.001
Blade tenderization × aging temperature interaction				
Blade tenderized	−0.5°C	22.57	14.1	45.5
Blade tenderized	3.3°C	22.78	13.3	52.9
Non-blade tenderized	−0.5°C	22.40	21.1	40.9
Non-blade tenderized	3.3°C	22.83	18.7	54.4
SEM		0.14	0.43	1.61
$P > F$		0.45	0.07	0.06
Blade tenderization × aging time interaction				
Blade tenderized	12 d	22.93	15.3	38.1
Blade tenderized	26 d	22.30	14.0	48.6
Blade tenderized	40 d	22.81	11.8	60.8
Non-blade tenderized	12 d	22.91	20.5	40.9
Non-blade tenderized	26 d	22.41	20.6	43.9
Non-blade tenderized	40 d	22.53	18.6	58.1
SEM		0.17	0.53	1.98
$P > F$		0.51	0.21	0.15

[x–z]Least squares means within a column and within an effect lacking common superscripts differ ($P < 0.05$).

distributions and is not intended to represent a threshold for consumer acceptability.

The effect of blade tenderization on gluteus medius tenderness was relatively large (6.3 kg). Furthermore, the proportion of non-blade-tenderized gluteus medius steaks stored at 3.3°C with slice shear force values greater than 25 kg was much larger than the proportion of blade-tenderized steaks stored at −0.5°C with slice shear force values greater than 25 kg. The relatively high frequency of non-blade-tenderized steaks with slice shear force values greater than 25 kg may suggest that too many consumers would have a poor eating experience to maintain customer satisfaction. Our conclusion is that, depending on the expectations of target consumers, tenderness differences between blade-tenderized and non-blade-tenderized steaks were likely small enough in the longissimus lumborum to justify using longer aging times at 3.3°C instead of blade tenderization. However, aging alone (at either temperature) did not sufficiently tenderize gluteus medius steaks.

Tenderness improvements due to blade tenderization were larger than those attributable to extended aging at 3.3 or −0.5°C. Smith et al. (1979a) reported that, for loin steaks, blade tenderization and aging for 14 d produced similar improvements in tenderness ratings and shear force values and that those effects were additive. Savell et al. (1982) reported that the effect of increasing postmortem storage from 4 to 18 d on sensory panel tenderness ratings was approximately twice as large as that of blade tenderization in longissimus steaks. However, those investigators reported slightly smaller improvements associated with aging than with blade tenderization in gluteus medius. The shortest aging time examined in the present study was comparable with the longest aging time tested by Smith et al. (1979a) or Savell et al. (1982). George-Evins (1999) reported that LM steaks that were blade tenderized twice had similar improvements with increased aging from 14 to 21 d as steaks that had not been blade tenderized.

In our study, approximately 50 and 40 percent of desmin had been degraded in the longissimus lumborum and gluteus medius steaks after 12 d of storage (15 d postmortem), respectively. During the next 28 d of storage, desmin degradation increased by less than 20 percentage points in both muscles, suggesting that the greatest improvements in tenderness had already occurred. This notion is supported by Gruber et al. (2006) who reported that the rate of tenderization in the longissimus lumborum and gluteus medius decreased with increasing aging time. Therefore, the smaller effect of

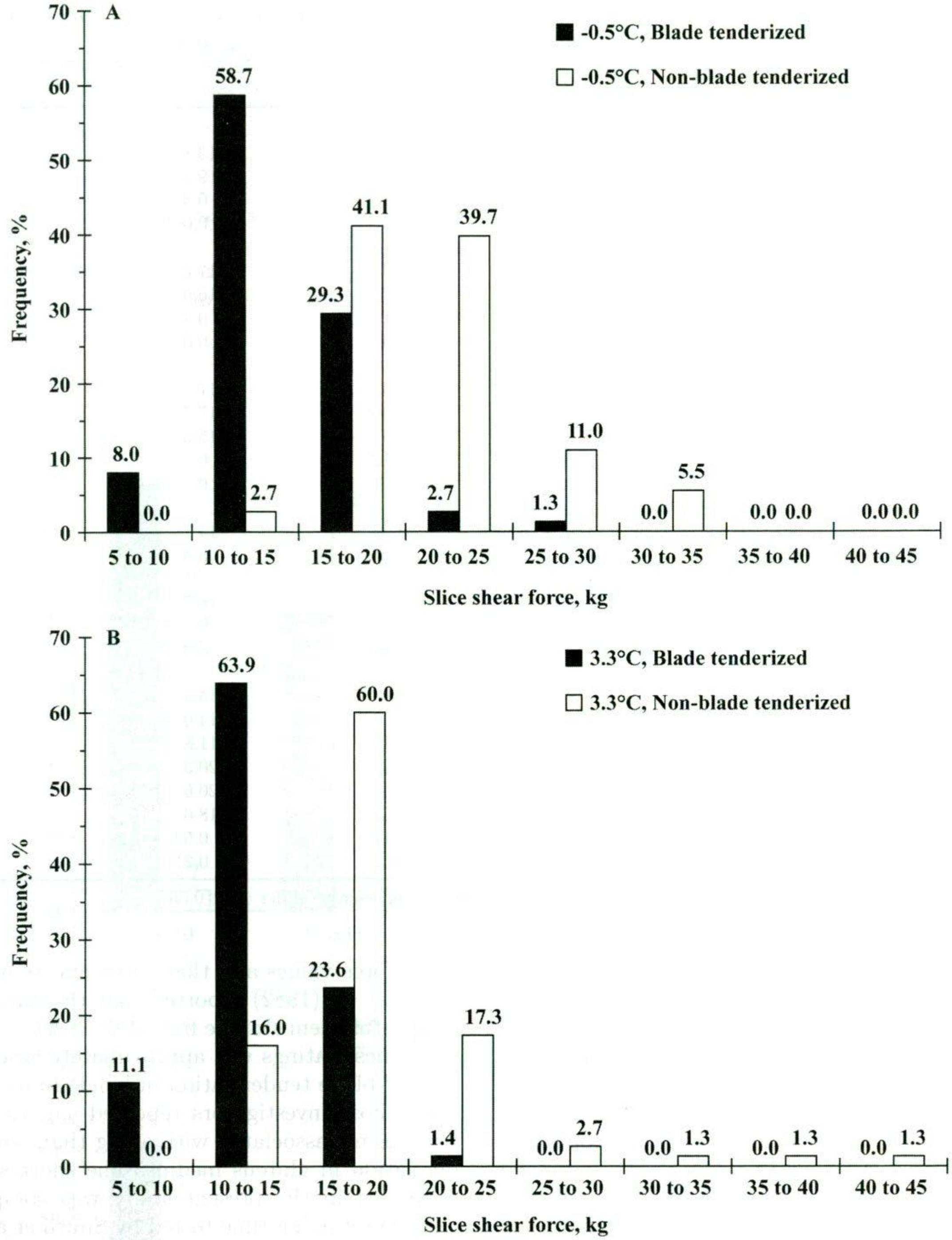

Figure 2. Frequency distribution of slice shear force values for blade-tenderized and non-blade-tenderized gluteus medius steaks aged at −0.5°C (A) or 3.3°C (B).

additional aging in comparison with that of blade tenderization in the present study was not surprising.

Because blade tenderization improves tenderness by physically disrupting the contractile and connective tissue structures of the muscle, it was not surprising that this treatment did not affect proteolysis. In the present study, aging non-blade-tenderized longissimus lumborum steaks beyond 12 to 26 d resulted in further desmin degradation and reduced slice shear force values though the improvements in slice shear force may be too small to be of importance to consumers. Increased aging from 26 to 40 d further decreased slice shear force values, even though no further increase in desmin degradation was detected. However, blade-tenderized longissimus lumborum steaks did not improve with aging beyond 12 d. Additionally, increasing aging time from 12 to 26 d did not affect slice shear force values of gluteus medius steaks, but further aging to 40 d at the prescribed temperature produced an improvement in slice shear force values regardless of blade tenderization treatment. Each of these increments in aging time resulted in an increase in desmin degradation. It is surprising that the increase in desmin degradation gluteus medius steaks between d 26 and 40 was larger than the increase between d 12 and 26. However, this difference is consistent with slice shear force and is likely due to animal differences in tenderness.

In agreement with these findings, George-Evins et al. (2004) found that aging time (7 to 21 d) effects on Warner-Bratzler shear force values of gluteus medius steaks were not influenced by blade tenderization. Savell et al. (1982) found that increased aging time from 4 to 18 d improved tenderness ratings of blade-tenderized and non-blade-tenderized gluteus medius steaks. However, those authors reported that aging time had no effect on Warner-Bratzler shear values of non-blade-tenderized gluteus medius steaks, but improved Warner-Bratzler shear values of steaks that had been blade tenderized.

Previous data from our laboratory indicated that slice shear force of non-blade-tenderized gluteus medius steaks decreased between aging intervals similar to those used in the present study (14 to 28 and 28 to 42 d), though desmin degradation did not differ between d 14 and 28 in that study (King et al., 2009). Reports regarding aging in the longissimus lumborum (Smith et al., 1978; Gruber et al., 2006, 2008) and gluteus medius (Harris et al., 1992; Eilers et al., 1996; George et al., 1999; Gruber et al., 2006) suggest that, in general, longer extended aging times will result in greater proteolysis and improved tenderness, though these changes are not linear and may not be large enough to be statistically significant at all incremental increases in time.

The mechanism of tenderization during postmortem storage is the proteolytic degradation of key cytoskeletal proteins by the calpain enzyme system (Koohmaraie, 1994, 1996). The rate of calpain-mediated proteolysis is somewhat temperature dependent (Koohmaraie et al., 1986; Zeece et al., 1986; Koohmaraie, 1992). In vitro studies on prerigor excised muscle suggested that increases in temperature as small as 5°C increase the rate of tenderization (Davey and Gilbert, 1976; Dransfield et al., 1981). Additionally, delaying or slowing temperature decline of carcasses for several hours before chilling has been reported to improve tenderness independent of sarcomere length (Lochner et al., 1980; Marsh et al., 1981; Crouse and Seideman, 1984). Conversely, rapid chilling has been shown to reduce the rate of early postmortem proteolysis (King et al., 2003). However, very little published data are available regarding the effect of small temperature changes on the aging response of intact postrigor muscle. This increase of desmin degradation in longissimus lumborum steaks was sufficient to reduce slice shear force values in non-blade-tenderized steaks but not in blade-tenderized steaks. Blade tenderization did not affect the reduction in slice shear force due to greater temperatures in gluteus medius steaks. Additionally, increased temperature improved the distribution of slice shear force values in both muscles. In contrast to our findings, Carpenter et al. (1976) evaluated top sirloin butts fabricated at 1 or 7.2°C and stored (7 to 35 d) at 0 or 5.5°C and found no differences in tenderness ratings or Warner-Bratzler shear force values due to time or temperature of postmortem storage.

The improvements in slice shear force associated with such a small temperature gradient may not be large enough to merit the changing of aging procedures. Certainly, other issues such as shelf life would need to be considered before making such a change. This finding also may have implications for interpreting research data because aging temperature may influence the detection of treatment differences, particularly if those differences are small.

In conclusion, the use of blade tenderization and extended postmortem aging are commonly used throughout the food-service segment of the beef industry. However, a noninvasive tenderization method is desired as an alternative to blade tenderization due to food safety concerns. The present study demonstrates that a relatively small increase in the temperature during postmortem storage could enhance the effectiveness of aging protocols. Furthermore, longer aging could possibly be a suitable replacement for blade tenderization in longissimus lumborum steaks. However, extended postmortem aging alone likely would not eliminate the incidence of extremely tough gluteus medius steaks and could not be used to eliminate blade tenderization in that muscle.

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